Renewable and Sustainable Energy Reviews 16 (2012) 2913–2919

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Progress in renewable energy under clean development mechanism in India

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ARTICLE INFO

Article history:
Received 12 July 2011
Accepted 5 February 2012
Available online 22 March 2012

Keywords:
Renewable
India
Energy
CDM

ABSTRACT

Kyoto protocol was the first agreement regarding control of climate change problems. Clean development mechanism (CDM) was included in the Kyoto protocol to promote sustainable development in developing countries (non-Annex I countries) and assist developed countries (Annex I countries) to achieve their emission reduction targets. CDM allows trading of emissions reductions and helps to increase sustainable development in a developing country and reduce global emissions in developed country. Renewable energy sources are the appropriate alternatives for sustainable development through CDM. India is one of the emerging nations in renewable energy sector. Government of India is trying to enhance energy generation through renewable and carbon trading. This paper shows the current status and progress of renewable energy through CDM in India.

Contents

1. Introduction

Minimization of the harmful environmental impacts by reducing the green house gas (GHG) emissions in the atmosphere is the main aim of United Nations Framework Convention on Climate Change (UNFCCC). The climate change convention is an agreement by United Nations which raises the problem on critical changes in climate. The convention was taken seriously by United Nations Conference on Environment and Development (UNCED) in Rio, Brazil in 1992. In 1997 a protocol was outlined in Kyoto city Japan to implement the climate change convention. In Kyoto Protocol, the developed countries are insisted to reduce their emissions to specific targets. Kyoto protocol was the first agreement regarding environment issues to control the climate change problem. Three flexible mechanisms were included by Kyoto protocol viz. Emissions Trading, Joint Implementation and clean development mechanism (CDM). Among these mechanisms, CDM is quite able to enhance sustainable development in developing countries (non-Annex I countries) and assist developed countries (Annex I countries) to achieve their emission reduction targets [1,2]. CDM is a compensating mechanism originated under Kyoto Protocol to promote sustainable development in developing countries. CDM allows trading of emissions reductions from sustainable projects or projects having emission abatement objectives. Basically, there are two objectives of CDM: It helps to increase sustainable development in a developing country and help to minimize GHG emissions in developed country so that environmental problems can be reduced. Consequently, CDM acts as mode of technology transfer to developing countries. Today, several projects throughout the world have been registered under CDM due to which it has become a huge

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doi:10.1016/j.rser.2012.02.008

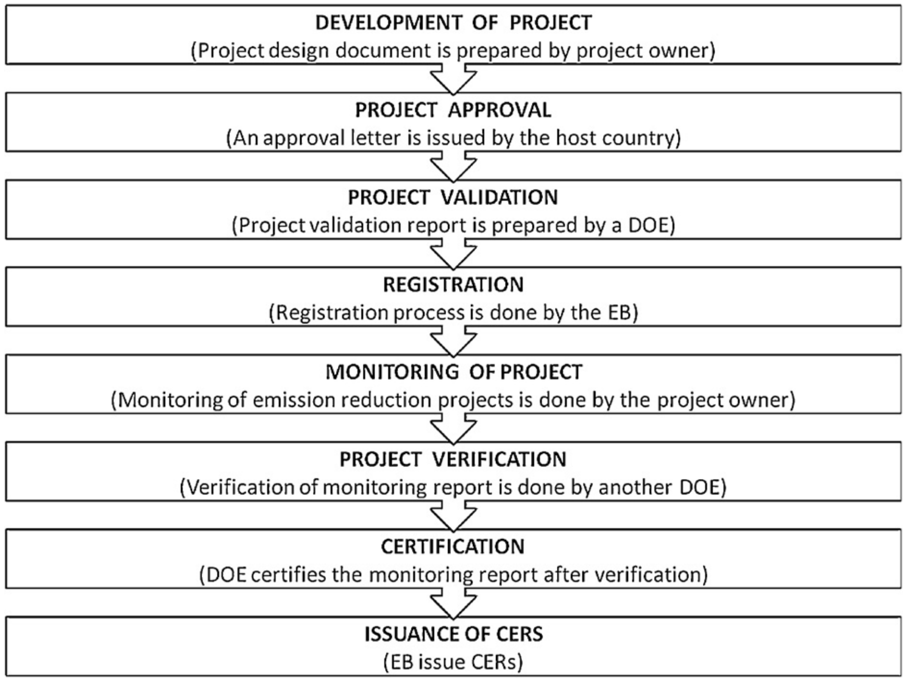


Fig. 1. CDM project cycle.

global market. It allows the developing countries to sell emission credits known as 'certified emissions reductions' (CERs). CERs are the measure of benefit of GHG emission reduction in CDM projects. CERs are commonly expressed in tonnes of CO_2 emissions reduced during operation of a project. One tonne of CO_2 is equivalent to one CER. In addition to this other gas emissions like methane, nitrous oxide, etc. can also be expressed in same units by converting them into CO_2 equivalent.

The activities regarding promotion, implementation and supervision of CDM projects are handled by a CDM executive board (EB) which is comprised of members of the parties of the Kyoto Protocol representing different economic alliances and bodies. The EB was created in Conference of Parties (COP) 7 to carry out the daily supervision of CDM projects [3]. The EB authorize some firms to perform various tasks related to promotion, implementation and supervision of CDM projects and these firms are known as designated operational entities (DOEs). If any project follows all criteria approved during COP 7 held in Marrakech for CDM projects then it can be eligible for CDM registration and can earn emission reduction credits. However final rules and criteria regarding CDM registration were acceded in COP 8 held in New Delhi in 2002.

There are mainly seven stages in CDM project cycle as shown in Fig. 1. First of all, a project proposal document which is commonly known as project design document is prepared by the project developer. The project design document is verified by a designated operational entity (DOE). In addition to this an approval letter from the designated national authority of the host country is mandatory. After this the DOE sends its report regarding the project with project design document and approval letter to EB for the CDM registration. After the registration process the project owner monitors emission reductions by the project and sends the monitoring report to another DOE. The DOE approve the monitoring report after finding the monitoring of emission reductions claimed by the project owner satisfactory and then certifies to the EB. After this the EB issues required amount of CERs to the project owners [4].

To achieve the main goals of CDM i.e. achieving sustainable development and reducing emissions renewable energy projects seem most promising due to their cleanliness and non depleting characteristics. Due to population growth and rapid increase in energy demands the need for exploring new, clean and sustainable sources for energy generation has been increased. Renewable energy sources are one of the most important and useful sources for sustainable energy development. They are the most suitable solution for environmental problems like climate change, global warming, acid rain, etc. Liu et al. [5] carried out a study to analyze the influence of renewable energy on the mitigation strategy of China. The analysis included the analysis and comparison of CO_2 mitigation costs, mitigation potential, energy conservation capacity of renewable energy and other mitigation options. The study concluded that the proper utilization of renewable energy is very essential for saving petroleum products and obtaining large CO_2 mitigation and its benefits can be explored more by providing proper policy, funding and technical support.

As environmental problems and climate change are the major complications in sustainable development. There is a good match between renewable energy technologies and CDM so they can contribute a lot in sustainable development [6]. Many developed and developing countries throughout the world are concentrating on promotion of renewable energy based electricity generation [7]. In 2009, the power generating capacity through renewable sources has been reached to 1230 GW which is about 26% of total capacity worldwide as shown in Fig. 2 [8]. In addition to this about 300 GW generating capacity has been added to the world's grid in 2009 out of which 47% is from renewable energy sources.

The status of renewable energy power generating capacities is shown in Table 1. The figures of Table 1 show that India shares about 4.5% of world's total renewable energy based electricity generation and growing as one of the leading nations in renewable energy development.

India is one of the supporting nations of UNFCCC and trying to explore and develop the scope of CDM projects so that the problem of GHG concentrations and climate change is reduced. Ministry of new and renewable energy (MNRE) Govt. of India is taking all necessary steps to promote the CDM projects. According to the seventh conferences of parties (COP-7) to the UNFCCC, the nations taking part in CDM should constitute or designate a national

Table 1
Renewable energy power generation in 2009 (units in GW) [8].

Source	EU-27	China	United States	Germany	Spain	India	Japan	World total
Wind power	75	25.8	35.1	25.8	19.2	10.9	2.1	159
Small hydro[a]	12	33	3	2	2	2	4	60
Biomass	16	3.2	9	4	0.4	1.5	0.1	54
Solar photovoltaic	16	0.4	1.2	9.8	3.4	0	2.6	21
Geothermal	0.8	0	3.2	0	0	0	0.5	11
Solar thermal power	0.2	0	0.5	0	0.2	0	0	0.7
Ocean power	0.3	0	0	0	0	0	0	0.3
Total	120.3	62.4	52	41.6	25.2	14.4	9.3	306

[a] Plants having capacity less than 10 MW.

Table 2
Approved CDM projects in India by NCDMA [9].

S. No.	Sector	No. of projects	No. of CER annual	No of CER (2012)
1.	Energy industries (renewable/non-renewable sources)	145	13,921,355	11,684,206
2.	Energy demand	8	270,655.6	459,544
3.	Manufacturing industries	9	438,482	798,484
4.	Metal production	1	798,347	1,197,521
5.	Transport	1	390	500
6.	Waste handling and disposal	3	782,858	396,562

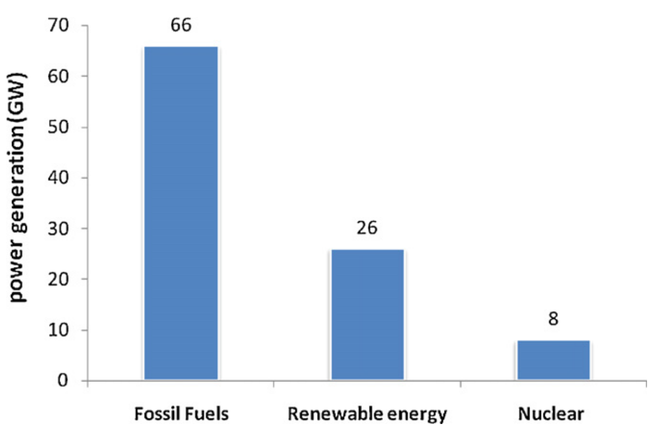


Fig. 2. Generation capacity by various sources in 2009.

authority as discussed while describing the CDM project cycle in Section 1. Ministry of environment and forest, Government of India has established National Clean Development Mechanism Authority (NCDMA) in 2003 for promoting CDM projects in India. However the first project from India was registered in March 2005. NCDMA evaluates and approves projects according to the guidelines and modalities issued by CDM executive board and conference of parties serving meeting of UNFCCC. In addition to this, NCDMA carry out various activities to provide all necessary and reliable information to project developers by compiling and publishing statistical data related to CDM. Table 2 shows the list of CDM projects in various sectors approved by NCDMA. These CDM projects have been executed by Government, state Government and private organizations in India.

2. Renewable energy development in India

India is one of the developing countries having huge potential for renewable energy. Also, it one of the fast growing economies of the world and it require a huge amount of energy supply. Therefore, renewable energy sources are the appropriate solutions to meet this high energy requirement [10]. MNRE, Govt of India is effectively working on the promotion and implementation of renewable energy and serving as a very important member to promote CDM and reduce critical impacts of climate change. The development of various renewable energy sources is discussed for the following.

2.1. Biomass

Biomass is one of the important renewable energy sources and effective for cleaning our environment by trapping carbon dioxide. The biomass is widely used in India for household cooking and heating. Country's 32% of the total energy is supplied from it. The types of biomass commonly used are wood, charcoal or dried dung, rice husk, straw, coffee waste and other agriculture waste. The overall potential of biomass including bagasse cogeneration is 18,000 MW out of which around 13% is harnessed. The development of biomass power in India is shown in Table 3. The geographical conditions of India support to create an ideal environment for biomass development. This is due to ample amount of solar radiations and precipitation in the country.

Around 259 biomass power and cogeneration power projects have been installed in India for electricity generation. There is a huge potential of CO_2 mitigation by baggase cogeneration in the country [12]. Also, 135 projects are under implementation stages. Andhra Pradesh, Chattisgarh, Maharashtra, Karnataka, Tamil Nadu and Uttar Pradesh are the states having good development of biomass electricity generation as shown in Fig. 3.

Biomass power generation and bagasse based cogeneration in sugar mills have been initiated under biomass power and cogeneration program. In sugar mills, bagasse can be used as a fuel to produce high temperature and pressure steam which can be utilized in sugar preparation as well as electricity generation.

The major benefit of the biomass is the rural economic development in both developed and developing countries. It is widely available in rural areas due to abundance of high agricultural and plants wastes and thus it is an effective source to provide the

Table 3
Biomass power in India[a] [11].

S. No.	Source	Potential achieved (MW)
1.	Biomass (agriculture residues)	901.10
2.	Bagasse cogeneration	1411.53
	Total	2312.63

[a] On 30-06-2010.

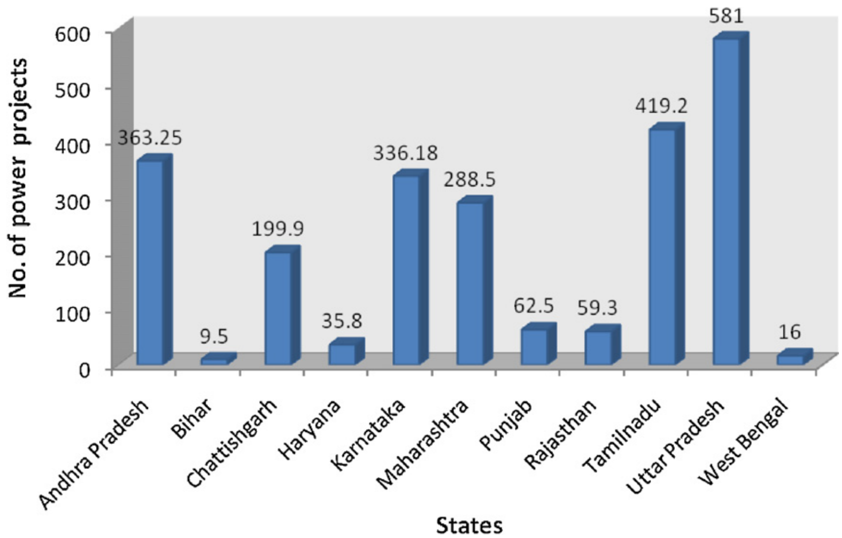


Fig. 3. State-wise commissioned biomass power/co-generation (MW) in India.

energy in rural areas. A study for East Asian countries tells that development of biomass power generation is very effective for energy security and rural development [13]. Benefits like derived support payments, increase of international competitiveness, revitalization of retarded rural economies attract to use biomass as an energy source. Purohit and Michaelowa [12] carried out a study to find out India's theoretical and realistically achievable CDM potential of bagasse cogeneration and concluded that power generation through bagasse cogeneration will not be according to its maximum estimated potential in another twenty years if past trends of bagasse cogeneration are considered. However, by advent of supportive CDM policies, it can be easier to achieve the maximum potential at speed.

In India, about Rs. 6000 million are invested every year in biomass power generation. In addition to this, several employment options are created with utilization of biomass in rural areas. MNRE, Govt. of India has started national programs for enhancing biomass power production. The objectives of these programs are to promote and explore some new technologies for efficient utilization of biomass resources of the country. In 11th plan (2007–2012), target 1700 MW electricity generation is fixed biomass (including cogeneration) with an investment of Rs. 8000 million. Government of India have been aiding financially to abolish financial barriers in biomass energy development. Organizations like NCDC (National Cooperative Development Corporation), IREDA (Indian Renewable Energy Development Agency) and Government banks are effectively working in implementation of policies pertaining to biomass. For development of better technical, efficient and environmentally suitable models in utilization of biomass energy, biomass based improved chulhas (stoves) are promoted for family, community, institutional and industrial applications. Several schemes like 80% accelerated depreciation, concession on import duty and excise duty, etc. have started to attract investors for biomass electricity generation. In addition to this preferential tariff rates are announced by State Electricity Regulatory Commissions as shown in Table 4.

Utilization of biomass as an energy sources have several environment benefits. Biomass energy utilization helps in minimizing the GHG emissions produced by human and industrial activities. Combustion of biomass produce large amount of methane. Methane and carbon dioxide pose significant threats but life cycle of methane is 20 times shorter than carbon dioxide in atmosphere. Methane can be captured from landfills, manure lagoons so that it is not escaped to atmosphere. Consequently, the captured methane can be used to generate electricity or power motor vehicles. The crops growing absorb the carbon dioxide and released while burning biomass. The amount of carbon sequestered can be greater than that released by combustion.

2.2. Small hydro

Small hydro is one of the most appropriate sources of renewable energy. India has very huge potential of small hydro i.e. about 15,000 MW. In India projects having capacity less than 25 MW comes under small hydro category. The water potential of India is quite high and appropriate for small hydro development. The Government initiatives are appreciable for promoting the SHP to improve energy scenario of the country and electrify remote as well as rural areas [14]. MNRE, Govt of India has explored several small water resources which are suitable for establishing SHP plants. Also private sectors are also invited by the Indian government to accelerate the growth of SHP generation. A digital simulator for SHP has been installed at AHEC (Alternate Hydro Energy Centre) for developing more skilled man power in SHP. The electricity generation through small hydro is increasing every year as a result of which renewable energy generation of the country is increasing appreciably for sustainable development. Table 5 shows the capacity addition of small hydro power (SHP) during last ten years.

Table 4
Tariff rates announced by State Electricity Regulatory Commissions in India [11].

S. No.	State	Tariff fixed by commissions in rupees/kWh
1.	Andhra Pradesh	4.05
2.	Chhattisgarh	3.90
3.	Gujarat	4.50
4.	Haryana	4.00
5.	Karnataka	3.59–4.13
6.	Kerala	2.80
7.	Maharashtra	4.98
8.	Madhya Pradesh	3.33–5.14
9.	Punjab	4.04
10.	Rajasthan	4.47–4.96
11.	Tamil Nadu	4.50
12.	Uttarakhand	3.06
13.	Uttar Pradesh	4.29–4.38
14.	West Bengal	4.36

Table 5
Capacity addition in SHP during last ten years [15].

Year	Target (MW)	Capacity addition (MW)
2002–2003	80	80.39
2003–2004	80	84.04
2004–2005	100	102.31
2005–2006	130	120.80
2006–2007	160	149.16
2007–2008	200	205.25
2008–2009	250	248.93
2009–2010	300	305.25
2010–2011	300	218.37

Till 31-01-2011.

Table 6
Wind energy potential in India [15].

S. No.	States	Potential (MW)
1.	Andhra Pradesh	8968
2.	Gujarat	10,645
3.	Karnataka	11,531
4.	Kerala	1171
5.	Madhya Pradesh	1019
6.	Maharashtra	4584
7.	Orissa	255
8.	Rajasthan	4858
9.	Tamil Nadu	5530
	Total	48,561

2.3. Solar photovoltaic technologies

Solar photovoltaic (SPV) technology is very attractive since they use sunlight as an input energy and gives electrical energy as output. It one of the most promising sources of electricity generation in a decentralized manner. SPV systems are commonly used for lighting and small electricity generation required in non-electrified areas.

India is effectively trying to deploy small SPV systems. Several programs have been initiated for development and exploration of SPV technology so that applications of SPV systems can be increased. SPV cells are successfully used as solar lantern, solar pumping water system, etc. and these products are commercially available in Indian market. In many situations, these products are economical than fossil fuels and other petroleum products.

MNRE, Govt. of India is giving efforts in technology development in SPV technology so that efficiency of SPV systems is increased. In 11th plan, following research areas are targeted to make solar applications more useful:

- poly silicon and other materials,
- efficient silicon solar cells,
- thin films materials and solar cell modules,
- concentrating SPV systems,
- design and development of process and test equipment.

Purohit [16] performed a study to find out CO_2 mitigation potential of solar home systems (SHSs) under CDM in India and concluded that the installation of SHSs in the country is below their respective potential. This is due to the reason that high investment cost is one of the major barriers in SHSs. However, SHSs have good tendency to displace emissions and achieve sustainable development in rural areas and their potential can be harnessed effectively by introduction of good supporting policies. Another study regarding the installations of SPV pump is carried out by Purohit and Michaelowa [17] which showed subsidy must be provided by the government to achieve high CDM potential of SPV pumps in rural areas.

2.4. Wind energy

Wind energy is one of the most promising renewable energy sources for electricity generation. India is having a vast coastal area and ample availability of wind. India has highest potential of wind energy among all renewable energy sources. After USA, Germany, Spain and China, India is the largest wind power producer in the world. The overall potential of wind energy in India is around 48,500 MW. Of the total potential, 12,009.48 MW has been harnessed for providing energy. Table 6 shows wind energy potential in various states of India.

MNRE, Govt. of India has surveyed wind resources throughout the country. The ministry is also being trying to facilitate implementation of demonstration and private sector projects through attractive policies. The main objective of wind energy program is to enhance the commercialization of wind power generation. In 1998, an autonomous organization "Centre for Wind Energy Technology" (C-WET) under MNRE was established in Chennai, Tamil Nadu for development of wind energy based electricity generation. C-WET has established about 1244 wind monitoring and wind mapping stations in India under "Wind Resource Assessment Program". Also, C-WET is going to prepare Indian Wind Atlas in association with Riso National Laboratory, Denmark. In North-Eastern Part of India, 20 wind monitoring stations at a height of 50 m has been sanctioned by MNRE.

2.5. Geothermal energy

There are around 400 medium to high enthalpy geothermal springs. The most promising provinces for geothermal resources in India are [18]:

(i) The Himalaya,
(ii) Sohana,
(iii) Cambay,
(iv) Son-Narmada-Tapi,
(v) The Godavari,
(vi) The Barren island in Andaman-Nicobar chain of islands.

India is being trying to explore geothermal resources in the country. Geothermal resources can effectively be used in power generation as well as space heating, cultivation, etc. National Geophysical Research Institute (NGRI), Hyderabad, India has traced and evaluated geo-electric structures in Tatapani in Chhattisgarh, Surajkund in Jharkhand, Badrinath-Tapovan in Uttarakhand, Satluj-Beas and Parvati Valleys in Himachal Pradesh and Puga in Ladakh Region, Jammu and Kashmir. Table 7 shows geothermal fields in India.

2.6. Fuel cells and hydrogen

Another alternative of electricity generation is fuel cells. In fuel cells, chemical reaction is done between hydrogen and oxygen.

Table 7
Geothermal fields in India [19].

S. No.	Geothermal field	State	Estimated (min) reservoir temperature (°C)
1.	Puga	Jammu and Kashmir	240
2.	Tattapani	Chattisgarh	120–150
3.	Tapoban	Uttarakhand	100
4.	Cambay Garben	Gujarat	160
5.	Badrinath	Uttarakhand	150
6.	Surajkund	Jharkhand	110
7.	Manikaran	Himachal Pradesh	100
8.	Kasol	Himachal Pradesh	110

Several organizations viz. Bharat Heavy Electricals Ltd. (BHEL) Hyderabad, Central Electrochemical Research Institute (CECRI) Karaikudi, Central Glass and Ceramic Research Institute (CGCRI) Kolkata, National Chemical Laboratory (NCL) Pune are working in development of fuel cells. Prototypes of polymer electrolyte membrane fuel cells (PEMFCs) and phosphoric acid fuel cells (PAFCs) have been developed and demonstrated for power production and transport area. Fuel cells may be good source for providing energy in industrial, transportation, residential sector and rural areas. In addition to this, hydrogen fuel based automobiles and small power generators are also useful in residential and industrial areas. Various scientific institutions in India are working in hydrogen energy projects [11].

3. Barriers in CDM

As discussed earlier a project developer gets CERs after the registration of a project under CDM. Also monitoring of the emission reductions by a project is one of the important stages in CDM project cycle and monitoring report is verified by a DOE. The verification of the monitoring report of emission reduction is an important issue and it requires some standards for verifying emissions reductions claimed by the project owner. Therefore the monitoring report is approved by using 'baseline'. Baseline can be defined as the emissions that would be produced in the absence of the CDM project. The amount of CER can be obtained by subtracting the actual emissions from the baseline emissions as shown in Fig. 4.

Although the calculation of CERs by using baseline methodology seems to quite simple but in actual practice this calculation is not so easy. This is due the reason that baseline is very difficult to be established. The main reason behind the difficulty of baseline is its hypothetical root because it is impossible to predict about the emissions if a CDM project is not implemented. Also, several baseline scenarios can be possible in the absence of a CDM project [20]. However EB has approved some baseline methodologies which are based on three different principles viz. past and existing emissions, emissions obtained from a course of action (economic), average emissions from similar projects in five years under same conditions. In addition to this, EB can approve other methodology depending upon the complexity of a project [3].

As the main objective of CDM is to reduce the net global emissions but in actual a project developer is allowed to generate one tonne emission at the cost of one tonne emission reduction in a host country. Consequently there is no effective emissions reduction is possible. So, the projects which do not contribute in emission reductions (business-as-usual) are not suitable for solving critical climate change issues. The issuance of CERs to business-as-usual projects is one of the most concerning issues in CDM. Therefore, additionality is one of the most important tools for successful implementation of the rules for minimizing the critical effects of climate change. EB has set some rules viz. barrier analysis on additionality of small projects. Additionality test is used to check a project whether it is additional or not.

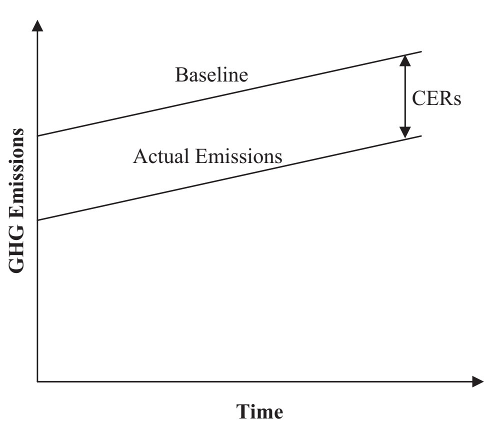


Fig. 4. Calculation of CERs using baseline.

The involvement of money making organizations in CDM projects is also a big impediment in sustainable development in rural areas. Subbarao and Lloyd [21] investigated the role of CDM in the development of rural areas by the development of small scale renewable energy projects. About 500 registered small scale projects under CDM were investigated for finding out their impact on the development of rural areas. In addition to this, five case studies from the Indian subcontinent were analyzed. The study showed that the small scale renewable energy based CDM projects can be very useful for rural development and deployment of renewable energy technologies. However, current position and design of CDM are inappropriate for achieving sustainable development in rural areas. The study also concludes that the projects having good community involvement and managed by cooperative ventures are more successful than the projects managed by money making organization.

Project developers are not much attracted by rural areas due to unavailability of good infrastructure and their distance from nearest center possessing renewable energy technologies. Therefore, the rate of implementation of CDM projects is low and still the rural areas required sustainable development.

Rio [22] explored the barriers affecting the implementation of renewable projects through CDM and showed that technology adaption and transfer, transaction cost, investor risks, project financing, low CER prices obstruct the deployment of renewable energy technologies through CDM. A study carried out by Lloyd and Subbarao [23] concluded that research is still required to tone up the relation between energy, climate and sustainable development. If the current status of CDM is modified then it can be helpful for sustainable development in rural areas. Also, Gilau et al. [24] concluded that further research on CDM should be focused on the removal of barriers in implementation of renewable energy to achieve sustainable development in developing countries as well as effective global emission reductions.

4. Conclusion

CDM is an important mechanism to reduce the global emission and promote sustainable development. It allows carbon trading due to which developed countries are attracted to invest in sustainable projects. Renewable energy sources play good role in accomplishing the main objectives of CDM. India has a huge potential of renewable energy. The total estimated potential of renewable energy in India is about 84,000 MW and electricity generation through renewable energy sources has been reached to 20.44%. In 2010 the energy generation through wind energy has been reached to 12,009.48 MW. Solar PV and biomass power is more than 12 MW and 901 MW respectively. The small hydro is providing 2767.05 MW which is 16.11% of the total renewable energy based electricity generation. In addition to these a good rise has been noticed on the growth of the fuel cell market. Government is also trying to explore geothermal sources for establishing geothermal power plants for electricity generation. Government policy measures are playing an important role in development and commercialization of renewable energy technologies and CDM projects. Consequently, many opportunities of the clean development mechanism in India are being explored. Although CDM is an effective mechanism for sustainable development and emission reductions but some barriers are also associated with it. Therefore it requires some more effective policy to reduce the barriers and make CDM

more effective to accomplish the objectives related to environmental protection.

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